

A late Holocene Vegetation and Fire Record from Ku-ring-gai Chase National Park, New South Wales

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Pollen and charcoal analyses of sediments from South Salvation Creek Swamp in Ku-ring-gai Chase National Park indicate that pollen influx has been dominated by local swamp species and dry sclerophyll heath and woodland taxa for the last 6000 radiocarbon years. Fire occurred throughout the record but charcoal and *Eucalyptus* pollen influx decreased over the last 1700 years. In an environment supporting dry sclerophyll vegetation fire appeared to play a constant role. The swamp surface was initially a sedgeland but was invaded by *Gleichenia* and woody shrubs around 2500 b.p. None of the vegetation changes could be ascribed directly to climatic shifts but the origin of the swamp itself may have been due to the postglacial rise in sea-level.

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INTRODUCTION

Ku-ring-gai Chase National Park encompasses 14,700ha of natural bushland 20km north of Sydney. A palynological investigation was undertaken on a peat swamp deposit on the southern arm of Salvation Creek on Lambert Peninsula (Fig. 1) to investigate vegetation change and possible vegetation-fire relationships during the mid to late Holocene. The elevation of the site (130m a.s.l.) assures that it has remained beyond any direct effects of sealevel change.

Ku-ring-gai Chase experiences a temperate coastal climate with a mean annual rainfall exceeding 1200mm. Mean maximum temperatures range from 26°C in January to 16°C in July whilst mean minima range from 17°C in January to 7°C in July. The prevailing winds are northeast to northwest in summer and southwest to southeast in winter (Bureau of Meteorology, 1979; Fitzpatrick and Armstrong, 1972; National Parks and Wildlife Service, 1982).

The rugged topography of Ku-ring-gai Chase is strongly influenced by the predominant rock type, Hawkesbury Sandstone. Shales and sandstones of the underlying Narrabeen Group outcrop along the foreshores of the Hawkesbury River. Lambert Peninsula is characterized by deeply dissected V-shaped valleys with narrow divides on the west and extensive areas of low slope on the plateau surface and steep coastal gullies on the east (Buchanan, 1975, 1980). Pittwater forms part of the drowned river valley of the lower Hawkesbury River.

The study site, South Salvation Creek Swamp, has developed in a broad shallow valley on the gently sloping plateau. Drainage has been impeded by massive quartz sandstone and clayey layers derived from shale lenses within the Hawkesbury Sandstone group. Lamy and Junor (1965a) described the importance of such swamps in maintaining a perennial flow to creeks, reducing flood flows on the lower sections, controlling erosion, and arresting sedimentation.

Soils derived from siliceous Hawkesbury Sandstone tend to be light-coloured sandy loams with low humus content, poor water-retaining properties and low fertility

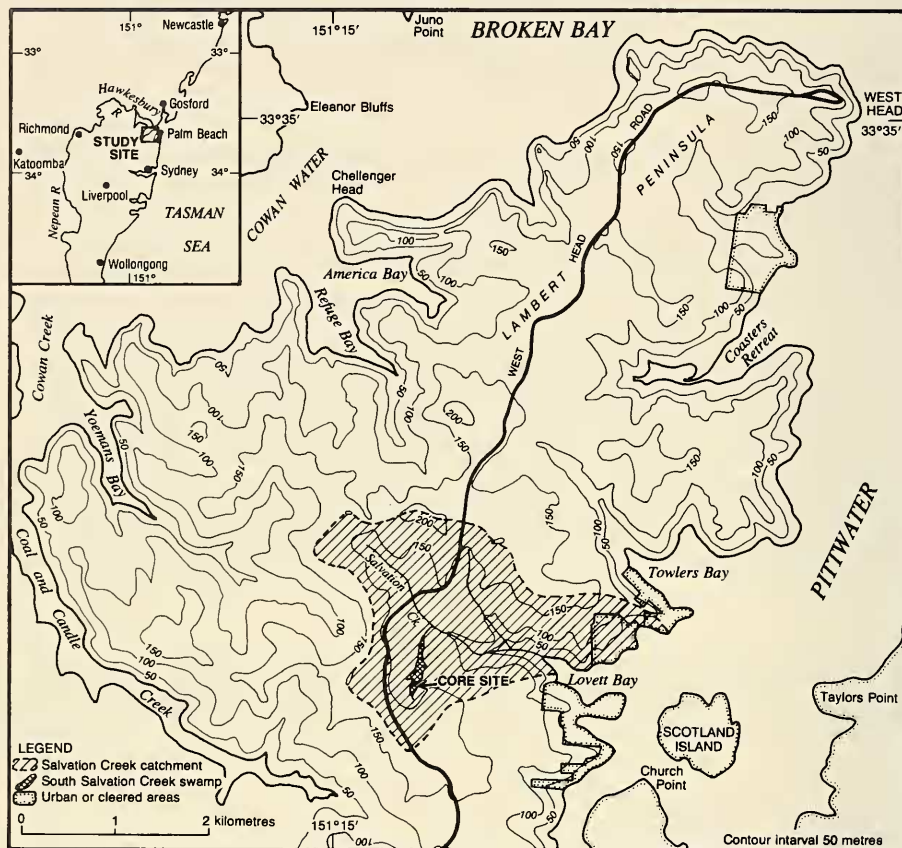


Fig. 1. Location of South Salvation Creek Swamp showing core location.

(Pidgeon, 1937; Lamy and Junor, 1965a, 1965b). On steep slopes and rocky outcrops sandy skeletal soils (lithosols) occur while deeper soils with some degree of profile development (towards yellow podzolics) are associated with the more gentle plateau slopes and hillslopes. Fine-textured loams of relatively higher-nutrient status, water-retaining capacity and humus content have developed on the Narrabeen shales.

The nature and distribution of the vegetation are strongly influenced by geology, topography, soil, drainage, aspect and fire (Buchanan, 1975, 1980; Kodela, 1984; Outhred *et al.*, 1985; Thomas and Benson, 1985). The dissected terrain and changes in lithology result in a complex mosaic of habitats and thus plant communities vary markedly in structure and floristics. The Salvation Creek catchment is dominated by woodland and heath on the exposed plateau surface and upper hillslopes while taller more mesic forests are confined to the sheltered lower slopes and gullies fronting Pittwater.

Descriptions are based on Thomas and Benson (1985) for terrestrial communities and Buchanan (1980) and Kodela (1984) for other types. Closed-scrub and heath occur in poorly-drained areas on the plateau, and shallow sandy soils on rocky sandstone outcrops. Shrub species commonly associated with moist heath include *Banksia ericifolia*,

Allocasuarina distyla and *Hakea teretifolia*. Occasionally *Eucalyptus haemastoma* and *Eucalyptus gummifera* occur as emergents. Low woodland and low open-woodland occur on the better drained lithosols and sandy clay loams on ridges, crests and low to moderately sloping benched hillslopes. Common tree species include *E. gummifera*, *E. haemastoma* and *E. oblonga* often with a diverse shrub layer characterized by species from the families Epacridaceae, Fabaceae, Myrtaceae, Proteaceae and Rutaceae. Sheltered slopes with south to southeast aspects support open-forest of *E. piperita* ssp. *piperita*, *Angophora costata* and *E. gummifera*. The deeper more fertile soils on the shale and colluvium-derived soils of the lower slopes support *Eucalyptus maculata*, *E. paniculata*, *Allocasuarina torulosa* and *Syncarpia glomulifera*. Sheltered coastal gullies may contain small pockets of rainforest with *Ceratopetalum apetalum*, *Tristaniopsis laurina*, *Acmena smithii*, *Livistona australis*, *Synoum glandulosum* and *Elaeocarpus reticulatus*. South Salvation Creek Swamp has a complex of four swamp vegetation types (Buchanan, 1980). The dense cover is essentially sedge, fern and shrub-dominated. Below the tall (2-3m) emergent *Leptospermum juniperinum* there is a layer of *Banksia robur*, *Aotus ericoides* and *Gahnia sieberiana*. The surface layer is dominated by *Empodisma minus*, *Gleichenia dicarpa* and *Drosera binata*. Other swamp and moist heath species, often peripheral to the swamp, include *Gymnoschoenus sphaerocephalus*, *Xyris operculata*, *Lepidosperma* sp., *Sprengelia incarnata*, *Hakea teretifolia* and *Banksia ericifolia*.

METHODS

A vertical core of peat was extracted from the deepest sediment section with a Russian (D-section) corer (Jowsey, 1966). Subsamples at about 10cm intervals were dispersed in warm hydroxide, treated with hydrofluoric acid and acetolysis fluid (9 acetic anhydride: 1 concentrated sulphuric acid) and dehydrated through an alcohol series before the residue was mounted in silicone oil. The technique is based on that described by Erdtman (1969), Faegri and Iversen (1975) and Moore and Webb (1978). A minimum of 200 pollen grains and spores was counted for each sample depth and pollen sums for the percentage diagrams are based on the total count. Five peat samples were radiocarbon-dated to provide dates for the age-depth curve in Fig. 2 and the time scale in Figs 3 and 4. Loss-on-ignition was used as an estimate of organic content, and, using the point count method of Clark (1982), microscopic charcoal particles were counted as an index of fire activity.

RESULTS AND DISCUSSION

Stratigraphy

The core was predominantly herbaceous peat overlying a pallid inorganic layer of sand and clay. Within the peat the degree of humicity increased with increasing depth, from course fibrous peat at the surface to well-humified organic matter at the base. The gradual transition suggests a series of decay. The sediment can be summarized as follows:

Depth (cm)	Description
0-20	dense surface mat of undecomposed plant remains (mainly <i>Empodisma</i> and <i>Gleichenia</i>):
20-40	mainly water and living roots. Gradual transition to:
40-110	brown fibrous peat (<i>Turfa herbacea</i>), pH 4.5-5. Gradual transition to:
110-240	homogeneous fine fibrous clayey peat with charcoal fragments and quartz sand scattered throughout or in thin layers; pronounced H ₂ S odour. Distinct granular charcoal layer at base of peat (230-240cm). Sharp transition to:
240 +	grey light-medium sandy clay (<i>Grana/Argilla</i>). Bedrock was encountered at ca 285cm.

Age and Origin of Site

The organic sediment dates from between 5000 and 6000 b.p. and marks either a regional change to greater effective precipitation, probably as a result of higher post-glacial sealevel, or a local geomorphic event such as damming of a stream outlet to allow sedimentation to occur. There is no clear evidence of the latter however. Buchanan (1975, 1980) suggested that the swamps of the Sydney region may be representatives of a cycle of swamp build-up and destruction. She suggested that climatic changes appear to be responsible for the cycles; and even in the short term such fluctuations over decades can affect swamp boundaries. Very dry climatic conditions can crack the peat surface, enable fires to burn the sediments and promote erosion when followed by heavy rain. The charcoal layer at the base of the peat (i.e. peat-inorganic boundary) may be an indication of such a process; alternatively the charcoal may have been stored in the catchment until deposition and preservation began. Such substantial layers of charcoal at the base of other peat or clay deposits have been observed by several investigators (Clark and Colhoun, pers. comm.; Macphail, 1984; Dodson *et al.*, 1986) and may be due to flush of charcoal into the system once sediments are able to accumulate or indeed may be part of a changed environment which leads to sedimentation itself. On a smaller scale, possibly reflecting periods of drought and fire, scoured shallow depressions are common on the exposed Hawkesbury Sandstone plateau while other depressions are inhabited by mosses, herbs and small shrubs which build up soil and organic matter.

Due to the general lack of distinct layers within the peat radiocarbon dates were not related to stratigraphy. Fig. 2 shows a general increase in accumulation rates toward the present, due at least in part to compaction increasing with depth. It is from this curve that ages in the text are estimated.

Pollen and Charcoal Record

Fig. 3 shows abundance of pollen for individual taxa based on percentage of the total pollen sum for each sampled sediment depth; in Fig. 4 estimates of pollen influx are shown for the more abundant pollen types. In these diagrams the modern sample incorporates the uppermost 15cm of sediment. Samples at 40 and 45cm represent 5cm sample thicknesses, i.e. 40-45cm and 45-50cm respectively, while all other samples represent 1cm sample thicknesses at 10cm intervals. Influx values are not calculated for the surface or more minerogenic samples; and there are missing loss-on-ignition values at several depths. The Appendix shows likely genera and species represented by the pollen taxa on the diagrams.

Tree pollen was dominated by *Eucalyptus*, but the values for *Allocasuarina* and *Banksia* may also contain some representation from trees. The highest values for *Eucalyptus* occur prior to 1900 b.p. for both influx and percentage values.

Charcoal is present throughout the record with highest values for both influx and concentrations between about 1300 b.p. and 3000 b.p. Charcoal concentration shows a decline from about 500 b.p. There is no consistent small-scale correlation between *Eucalyptus* and charcoal but the highest values for both occur prior to 1900 b.p.

Dryland herbs are poorly represented. These include Asteraceae, *Gonocarpus*, Liliaceae, Poaceae and *Pteridium*. An increase in herb pollen influx after 2000 b.p. may represent disturbance as many species in this group are competitive when clearance occurs. Although some of the herb taxa show slightly higher abundance values corresponding to relatively high fire activity, as indicated by charcoal, in this part of the record there are no consistent associations.

The total pollen input into the site is dominated by swamp taxa such as *Gleichenia*, Cyperaceae and Restionaceae; and is therefore very local in nature. There is a general trend of increasing *Gleichenia* spores to the present while Cyperaceae may have

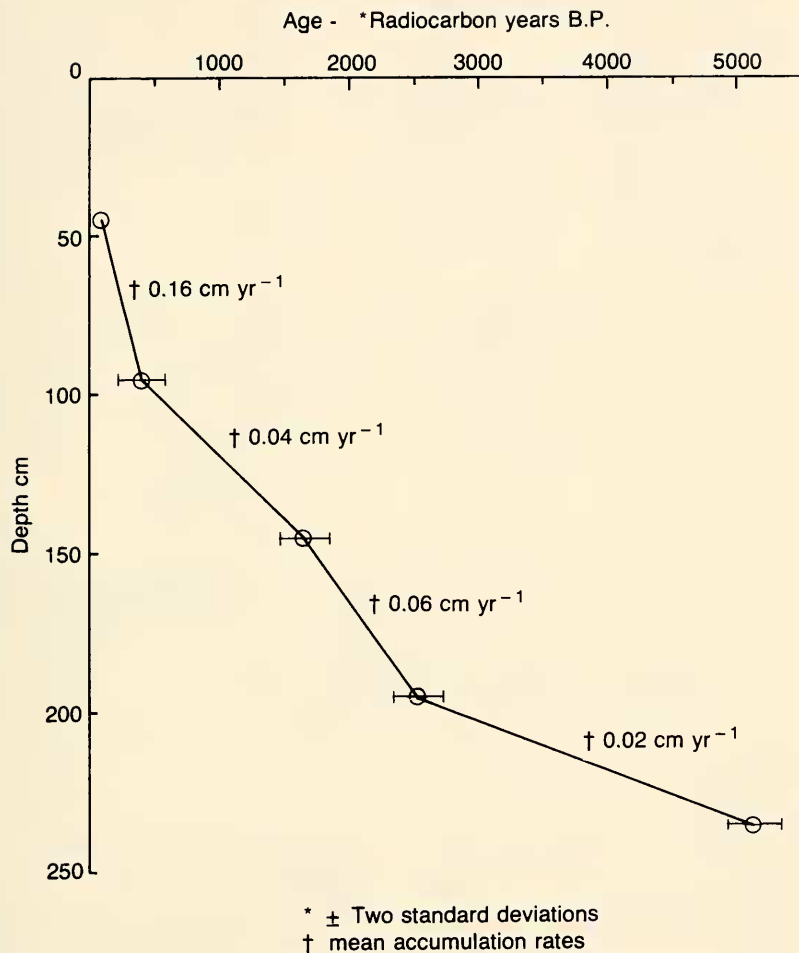


Fig. 2. Age-depth curve for the peat sediments.

decreased slightly. Restionaceae pollen increases markedly at 4900 b.p. where the peat layer overlies the inorganic sandy clay. Influx values for *Gleichenia*, Cyperaceae and Restionaceae appear somewhat cyclic, generally following changes in charcoal influx. Influx peaks for these taxa around 1700 b.p. and 500 b.p. correspond to peaks in charcoal and may indicate fires on or near the swamp promoting growth of these taxa.

Past Vegetation and Environmental History

There have been no marked changes in the flora; all the major pollen taxa remained

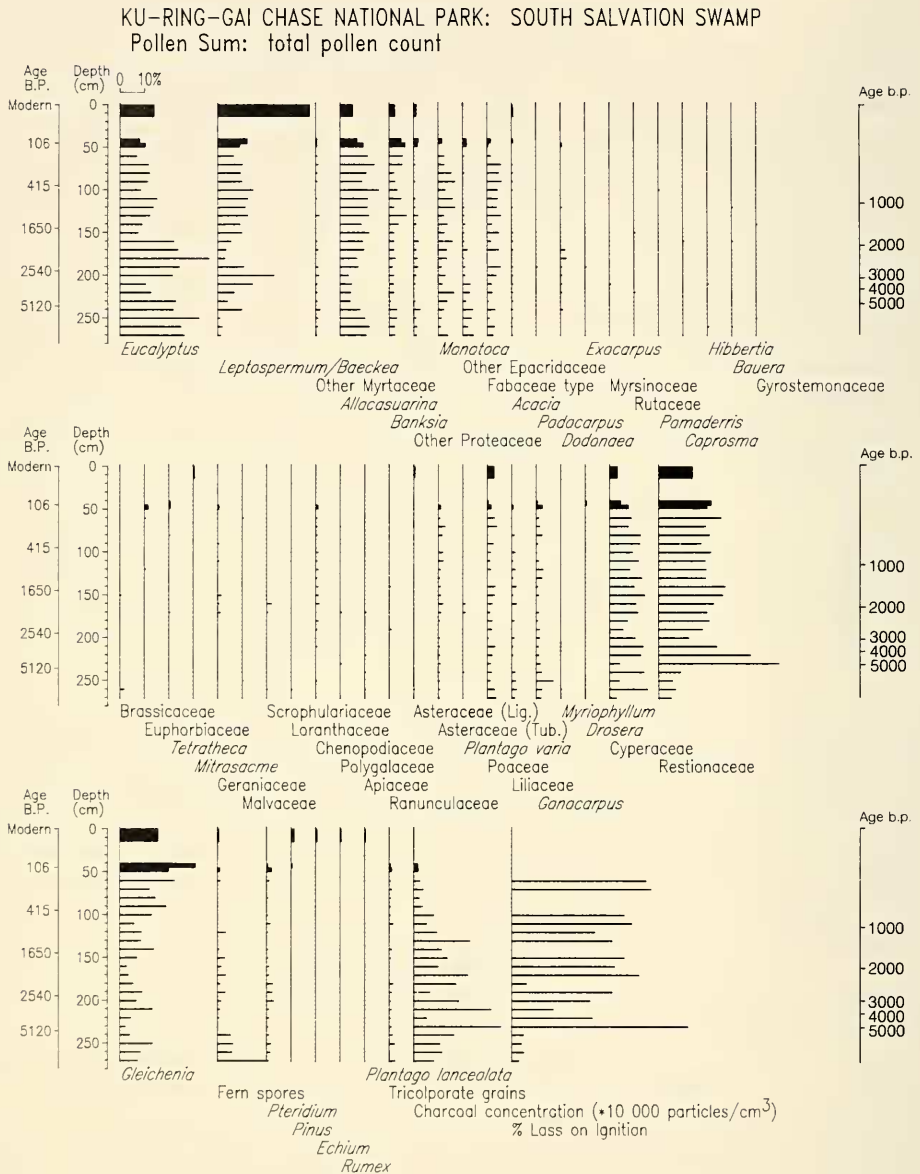


Fig. 3. Percentage pollen diagram from South Salvation Creek Swamp. In this diagram the modern sample incorporates the uppermost 15cm of sediment. Samples at 40 and 45cm represent 5cm sample thicknesses, i.e. 40-45cm and 45-50cm respectively, while all other samples represent 1cm sample thicknesses at 10cm intervals.

present throughout the record. The sandstone flora has retained its sclerophyll nature, reflecting stability and therefore resilience to nutrient-poor sandy soils, high insolation

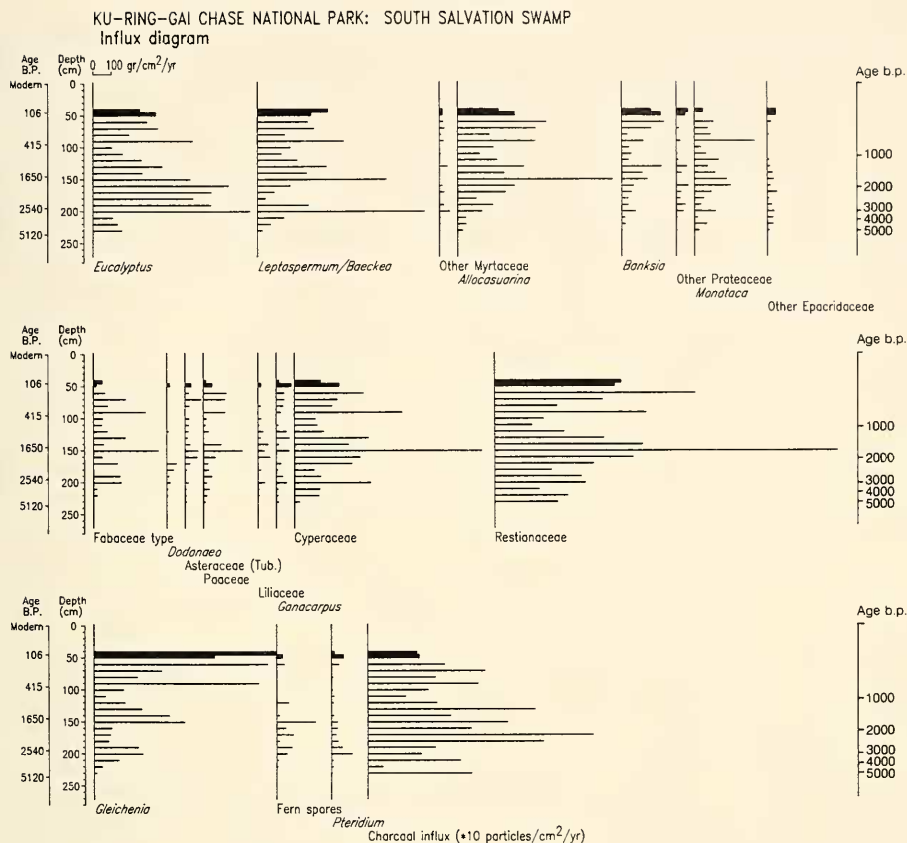


Fig. 4. Influx diagram for major pollen types from South Salvation Creek Swamp.

exposure, drought, and fire. Such vegetation is probably unlikely to be sensitive to minor environmental changes. Although the results show few or no changes in vegetation composition there are changes in relative abundances.

The pollen of many of the heath and understorey shrubs of woodland and forest communities is poorly dispersed, including that for *Acacia*, Epacridaceae, Fabaceae, Proteaceae and Rutaceae (Dodson, 1983). This explains the relatively low values for these taxa which are common in the vegetation at Ku-ring-gai Chase. Their under-representation in the pollen record does not reflect their true importance in the vegetation.

Fires appear to have been present throughout the record, reflecting a consistent association between fire and dry sclerophyll vegetation. There is a decline in charcoal within the last 200 years, coinciding with the arrival and settlement of European Man in the Sydney region. This may reflect the displacement of Aborigines and their burning practices. At the same time European presence is marked in the surface samples by *Echium*, *Pinus*, *Plantago lanceolata* and *Rumex* pollen.

Low loss-on-ignition values corresponding to thin sandy lenses appear with or above (indicating possible time lags) relatively high charcoal levels at around 4200 b.p.

and 2300 b.p. These are likely to indicate disturbance and erosion from the surrounding slopes.

Trends in pollen of swamp taxa show that the early swamp surface was dominated by Restionaceae, and possibly a fern other than *Gleichenia* during the more minerogenic deposition. Woody shrubs: *Banksia robur*, *Leptospermum juniperinum* and *Aotus ericoides*, prefer deeper sediments which could explain their general increases toward the present as a local successional effect. Increasing deposition would have created drier conditions on the swamp favouring their establishment and that of *Gleichenia*. Above this general trend smaller changes probably reflect local variations in water-table depth or the changing patterns of distribution of taxa by population fluctuations, interspecific competition, or fire.

Any relationship between charcoal influx and pollen abundance from swamp taxa could reflect fire adaptations of these taxa. Although normally much regeneration would be from rhizomes and suckering, the clearance of the thick *Gleichenia* and *Empodisma* cover would allow initial recruitment by seed dispersal, particularly of woody shrubs. Nutrient influx to the swamp after fires may also have some impact on the swamp vegetation. Fire may therefore be an important factor in swamp vegetation dynamics. A peak in *Leptospermum* pollen occurs with a decline in Cyperaceae, Restionaceae and *Gleichenia* around 2900 b.p. which could represent a dry period allowing *L. juniperinum* to expand on the swamp.

The initial major decline in *Eucalyptus* around 1800-1900 b.p. corresponds with a trend of increasing *Gleichenia* and swamp shrubs which may together represent climatic conditions becoming slightly drier and the eucalypt canopy opening towards a more woodland type. Alternatively the mire surface could have expanded laterally, thereby pushing back the eucalypt woodland and reducing the local eucalypt pollen input reaching the core site. *Eucalyptus* values may have been high in the past due to trees directly overhanging the site.

Chalson (1983) studied the vegetation record of Gibbon Swamp in Royal National Park south of Sydney. The site is located on a sandsheet overlying Hawkesbury Sandstone with the swamp set in the swale of a U-shaped dune about 1 km from the shoreline and 10 m above sea level. Chalson (pers. comm.) found *Eucalyptus* to be more common prior to about 5000 b.p. with *E. sieberi* pollen (possibly the mallee form of *E. sieberi* which occurs in the area today) highest around 4000 b.p. and declining to the present. At Kurnell Peninsula *Eucalyptus* declined after 2000 b.p. and was replaced by dune shrubs such as *Leptospermum* and *Monotoca* (Martin, 1986, and 1988 pers. comm.). These studies may suggest a regional decline in *Eucalyptus* in the late Holocene, a question worthy of further research.

The results show a very high local pollen input from plants growing on or near the swamp. For densely vegetated sites like South Salvation Creek Swamp it is difficult to separate terrestrial from swamp pollen where several genera have species representative in both habitats. For example, the source of *Leptospermum* pollen could be from the many woodland and heath species surrounding the swamp, however most of the pollen in the record is likely to be derived from *Leptospermum juniperinum* growing on the swamp. Such results emphasize the problems encountered when interpreting a pollen record derived from a complex mosaic of vegetation communities surrounding a swamp.

The lack of any consistent relationship between charcoal abundance and the behaviour of individual taxa reflects the complex relationships between vegetation and fire and the input of pollen and charcoal in the sediment. It may well be that the catchment area for charcoal differs from that of the pollen.

Plant taxa and communities are likely to have evolved and adapted to particular fire regimes rather than fire *per se* (Gill, 1975). Studying the effects of fire on vegetation

requires separating the components of the fire regime (intensity, frequency, type, time of occurrence etc.) and examining these in relation to the adaptations and life cycles of the plants (Kodela, 1984). Palynological techniques cannot readily differentiate these. Nevertheless broad relationships can be established and in this case there appears to be at least an association between high *Eucalyptus* and charcoal influx; perhaps reflecting an interdependence between the eucalypt species at the site and fire.

Although sclerophyll and swamp taxa appear to have dominated the record, fluctuations in their abundances and/or distributions have occurred. These are likely to be results of a combination of factors, including water-table fluctuations, seasonal drought, fire activity, interspecific competition, the natural changing patterns in species distribution and the impact of Aboriginal and European people. Changes in swamp and terrestrial pollen taxa around 2000 b.p. may indicate a drier climate to the present.

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APPENDIX

THE LIKELY ORIGINS OF THE MAIN TAXA IN THE POLLEN DIAGRAMS

Taxa identified in the pollen and spore record	The main or most likely genera and species represented by the preserved pollen and spores, and their ecology
<i>Eucalyptus</i> (includes <i>Angophora</i> spp.) <i>Leptospermum/Baeckea</i>	<i>Eucalyptus haemastoma</i> , <i>E. gummifera</i> , <i>E. oblonga</i> , <i>E. punctata</i> , <i>E. umbra</i> , <i>Angophora costata</i> etc. Forest and woodland trees. Would include <i>Leptospermum juniperinum</i> which grows on the swamp, <i>L. squarrosus</i> which occurs in moist heath communities and <i>Baeckea</i> spp., etc which occur in heath communities or as understory shrubs in woodland and forest communities.
Myrtaceae (other) <i>Allocasuarina</i>	Shrubs including <i>Kunzea</i> , <i>Callistemon</i> and <i>Melaleuca</i> . <i>A. distyla</i> (tall shrub to small tree in moist or dry heath communities), <i>A. torulosa</i> , and <i>A. littoralis</i> (trees in sheltered forest and woodland communities).
<i>Banksia</i>	<i>Banksia robur</i> (shrub growing on the swamp), <i>B. serrata</i> , <i>B. marginata</i> and <i>B. spinulosa</i> (common shrubs in woodland and heath communities), <i>B. ericifolia</i> (moist heath shrub).
Proteaceae (other) <i>Monotoca</i>	<i>Hakea teretifolia</i> (moist heath shrub) <i>Isopogon anethifolius</i> , <i>Petrophile pulchella</i> , <i>Conospermum</i> spp., <i>Grevillea</i> spp. etc. Shrubs in the forest, woodland and heath formations.
Epacridaceae (other)	<i>Monotoca elliptica</i> , <i>M. scoparia</i> . Shrubs in woodlands and heath.
Fabaceae	Some species occur on the swamp margin e.g. <i>Sprengelia incarnata</i> . <i>Leucopogon</i> (low heath or woodland shrub) encountered several times in the pollen record.
Euphorbiaceae	<i>Aotus ericoides</i> (woody shrub growing on the swamp) and many heath and woodland species such as <i>Dillwynia</i> spp., <i>Pultenaea</i> spp., <i>Bossiaea</i> spp., <i>Phyllota phylloides</i> .
Liliaceae	Mainly <i>Amperea xiphoclada</i> (low shrub)
<i>Gonocarpus</i>	<i>Xanthorrhoea</i> spp., <i>Thysanotus</i> spp., <i>Dianella</i> spp. Herbs in heath, woodland and forest communities.
Cyperaceae	<i>G. tetragynus</i> , <i>G. teucroides</i> , <i>G. micranthus</i> . Herbs in heaths and forests.
Restionaceae	<i>Gahnia sieberiana</i> , <i>Lepidosperma</i> spp., <i>Gymnoschoenus sphaerocephalus</i> , <i>Caustis</i> spp. Swamp and moist heath sedges.
<i>Gleichenia</i>	<i>Empodisma minus</i> , <i>Restio</i> spp. Swamp herbs. (Also on moist rock shelves and in moist heaths).
<i>Pteridium</i>	<i>Gleichenia dicarpa</i> . Fern growing on swamp and in other moist areas.
Fern spores	<i>Pteridium esculentum</i> . Often increases with disturbance.
<i>Pinus</i>	These include <i>Cyathea</i> , <i>Lycopodium</i> , <i>Blechnum</i> , Polypodiaceae, <i>Adiantum</i> and <i>Selaginella</i> . Understorey species in moist forests, near creeks, moist rock crevices, etc.
	<i>Pinus radiata</i> . Introduced trees.